• The role of echocardiography in sports cardiology

Right ventricular adaptation in endurance athletes.

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No conflict of interest
Right ventricular adaptation in endurance athletes.

• Summary:

• Cardiac adaptation to endurance training
  - General overview
  - The right ventricle specificity
  - Normal patterns/upper limits of normal

• May prolonged exercise be harmful for the right ventricle?

• How can we distinguish the normal adaptation from pathology (ARVC)?
Type of Exercise: Hemodynamic Effects

**Dynamic / Isotonic Exercise**

- Submaximal / prolonged / repetitive
- Large muscle group
- Aerobic metabolism
  - Increase CO / low TPR
  - Volume overload

**Static / Isometric Exercise**

- Rapid / intense / short duration
- Anaerobic metabolism
- Increase HR / TPR / SBP / DBP
- Pressure overload
Cardiovascular Adaptation to Exercise Training

Conditioning factors

- Type of exercise
- Intensity
- Frequency
- Duration
- Genetic
- Gender
- Age
- Ethnicity
Form follows function:
- *how muscle shape is regulated by work?*

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Left ventricle remodeling and adaptation to exercise training in athletes

End Diastolic Dimension and Wall Thickness in Athletes

A. Pelliccia et al. NEJM 1991

Physiologic Limits of LV Hypertrophy in Elite Junior Athletes:

Sharma S et al. JACC 2002

Physiological upper limits of LV cavity size in highly trained adolescent athletes – males vs females

Makan J et al. Heart 2005

Ethnic Differences in LV Remodeling in Highly-Trained Athletes

Basavarajaiah S et al. JACC 2008
Normal anatomy and physiology of the RV

- Complex geometry, crescent-shaped
- Heavily trabeculated and poor endocardial definition
- Ventricular interdependency
- Separate inflow and outflow
- Low resistance pulmonary circulation
- More dependent of preload and afterload
During exercise

Cardiac output \uparrow \uparrow \uparrow
Pulmonary resistance \downarrow \downarrow

NO synthetase
Metalloproteinases
↓ pulmonary vascular reserve
Other vasodilators factors

Cardiac output \uparrow \uparrow \uparrow
Systemic resistance \downarrow \downarrow \downarrow
How to assess RV morphology and function?

- Echocardiography
- CMR imaging
- CT imaging
- Radionuclide angiography
- RV catheterization
How to study the RV adaptation to exercise training in athletes?

GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afifalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California

(J Am Soc Echocardiogr 2010;23:685-713.)
Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: - A Report from the American Society of Echocardiography
Echo - RV morphology

Diastole

Diastole

Diastole

Diastole

Diastole

Diastole
Echo - RV systolic function

Fractional Area Change (FAC)

TAPSE

TDI derived RV function
Assessing - RV morphology and function
- New Echo Modalities

Myocardial Deformation Imaging

TDI derived Strain

2D Strain (Speckle Tracking derived)
Assessing RV morphology and function
- New Echo Modalities
- 3D Echo (RV volumes and EF)
Right ventricular adaptation in endurance athletes.

... what about the Right Ventricle?


Echocardiographic right and left ventricular measurements in male elite endurance athletes (127 athletes). cardiac enlargement occurs symmetrically in both right and left cavities. Henriksen et al. Eur Heart J 1996
Athlete’s Heart - Right and Left Ventricular Mass and Function in Male Endurance Athletes and Untrained Individuals Determined by Magnetic Resonance Imaging

J Scharhag et al. J Am Coll Cardiol 2002
Range of right heart measurements in top-level athletes: The training impact

- 650 top-level athletes (395 Endurance and 255 Strength trained)
- Echo evaluation

D'Andrea A et al. Int J Cardiol - 2011
Range of right heart measurements in top-level athletes: The training impact

- 650 top-level athletes (395 Endurance and 255 Strength trained)

RV - systolic Function

D'Andrea A et al. Int J Cardiol - 2011
The right heart of endurance athlete - morphology
Right ventricular adaptation in endurance athletes.

- Exercise induced cTn elevation
- Transient post exercise RV dysfunction
- Chronic RV abnormalities presenting with malignant arrhythmias
Troponin release following endurance exercise: is inflammation the cause? A cardiovascular magnetic resonance study

17 male athletes; CMR - 24 hrs pre and 6 hrs post-marathon. cTnI and NTproBNP -> 24 hrs pre, immediately after, and 6 hrs post-marathon.

**Conclusion:** Exercise induced cardiac biomarker release is not associated with any functional changes by CMR or any detectable myocardial inflammation or fibrosis.

Rory O'Hanlon et al. *J Cardiovasc Magn Reson* 2010
Right ventricular adaptation in endurance athletes.

• How can we distinguish the RV normal adaptation from pathology

Diagnosis of ACM / ARVC

Revised Task Force Criteria - Marcus F, McKenna W et al Circ – 2010

I. Global or regional dysfunction and structural alterations

II. Tissue characterization of wall

III. Repolarisation abnormalities

IV. Depolarization/conduction abnormalities

V. Arrhythmias

VI. Family history
# Diagnosis ARVC - Revised TFC 2010

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<thead>
<tr>
<th>Diagnosis</th>
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<tr>
<td>Possible</td>
<td>• 1 major</td>
<td>2</td>
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<td></td>
<td>• 2 minor</td>
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</table>
The right ventricle of the endurance athlete: the relationship between morphology and deformation

Oxborough D et al. *Heart* 2011
ARVC - Revised Task Force Criteria 2010

I. Global or regional dysfunction and structural alterations

By 2D echo: Regional RV akinesia, dyskinesia or aneurysm

- **and 1** of the following (end diastole):

  **major**
  
  - $\geq 32$ mm
    
    ($\geq 19$ mm/m²)
  
  - $\geq 36$ mm
    
    ($\geq 21$ mm/m²)

  **minor**
  
  - $\geq 29$ to $<32$ mm
    
    ($\geq 16$ to $<19$ mm/m²)
  
  - $\geq 32$ to $<36$ mm
    
    ($\geq 18$ to $<21$ mm/m²)

- Or fractional area change

  **FAC < 33%**

  **FAC > 33% to ≤40%**

Adapted from Marcus F et al Eur. Heart J 2010
ARVC or Physiological RV Adaptation?

- Symptoms
- Family Hx
- ECG abnormalities
- Ventricular Arrhythmias
- Wall motion Abnorm or RV dysfunction

- No Symptoms
- Negative family Hx
- Normal ECG
- No WMA or RV dysfunction
- Balanced Biventricular dilatation
How to distinguish ARVC from RV adaptation to exercise training?

• Clinical evaluation
• ECG and SAECG
• Holter monitoring
• Exercise stress test
• Echocardiography

• Cardiac Magnetic Resonance
• Angiography, EPS, EMB, Genetic testing, etc
Right ventricular adaptation in endurance athletes.

- How can we distinguish the normal adaptation from pathology

Male, 22 Y, Triatlon (< 2 h) (High level competition)  
Male, 22 Y, Triatlon (< 2 h) (High level competition)  
Male, 17 Y, soccer (Recreational)
RV adaptation in endurance athletes.

Conclusions:

• Increase RV cavity, inflow and outflow tract by Echo. Normal RV function at rest

• Increase RV mass and volumes by MRI, with ratio LV/RV maintained

• Most of the studies no correlation between transient RV dysfunction and cTn release

• No persistent myocardial dysfunction, inflammation or fibrosis by LE-MRI
RV adaptation in endurance athletes.

Conclusions:

• Physiologic RV adaptation may induce RV dilatation, but no WMA or RV dysfunction

• *Gray-Zone* Athletes' heart *vs* ARVC:
  ➔ Clinical evaluation, ECG, SAECG, Echo . . MRI . . and Genetic testing, EPS, EMB
Thank you for your attention!